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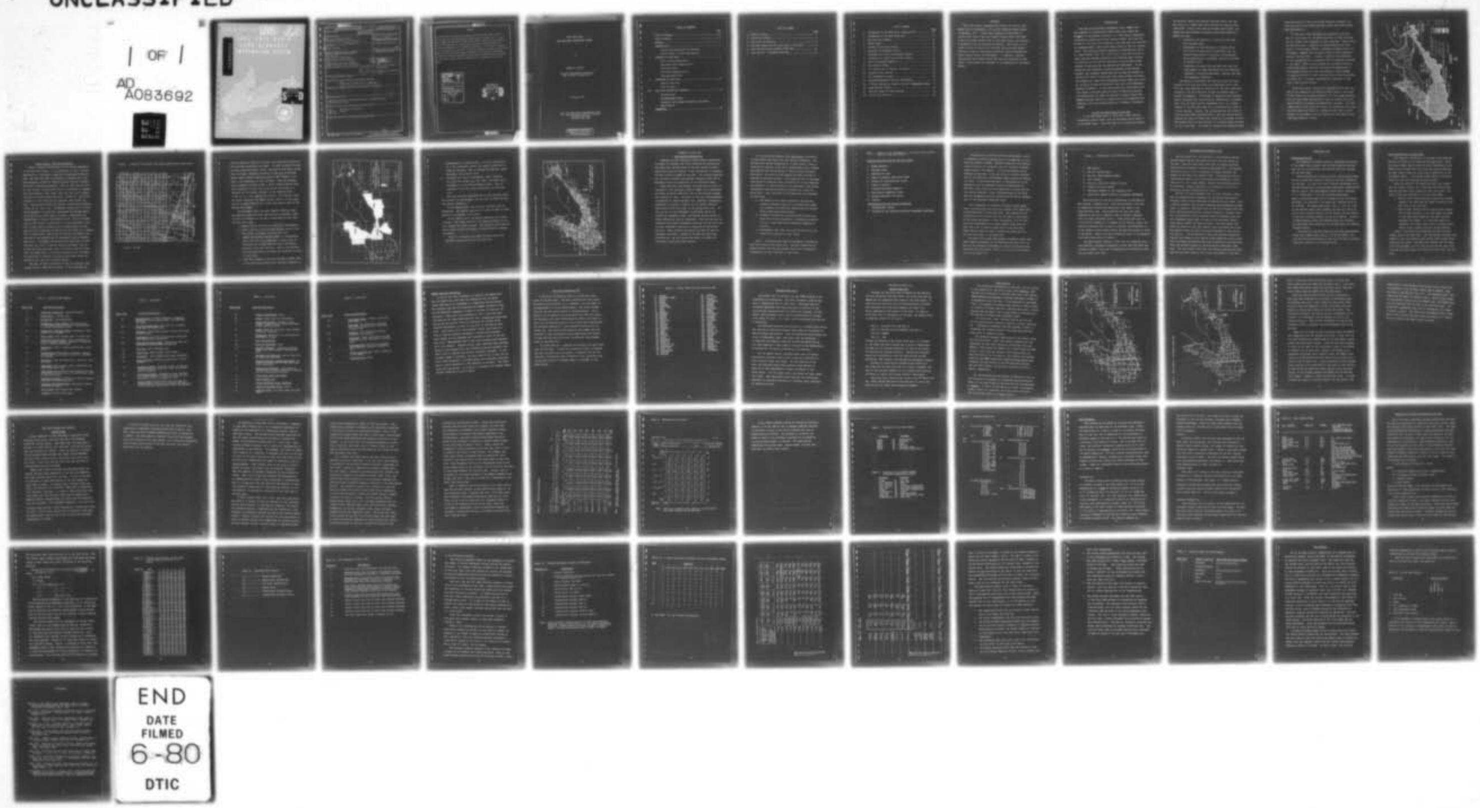

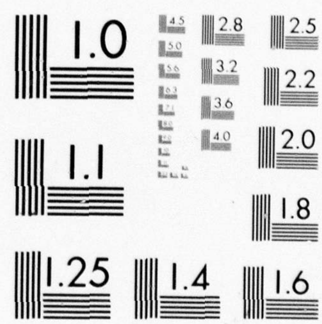

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ABSTRACT

This Final Report integrates and revises the initial LRIS Report dated 30 September 1977 and the Technical Report dated 14 December 1977. A great many changes have been made in various data files, codes and program formats during 1978 additions to the LRIS; please refer to the Users Manual and associated Appendices for any detailed information. This report is intended to give an overview of the LRIS, with the Users Manual providing a step by step guide through the various computer programs written during its development. In addition, selected applications and analyses using LRIS data are described in this report, while others are discussed in the Appendices to the Users Manual.

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LAKE ERIE BASIN

LAND RESOURCE INFORMATION SYSTEM

by

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January 1979

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ABSTRACT

This Final Report integrates and revises the initial LRIS Report dated 30 September, 1977 and the Technical Report dated 14 December, 1977. A great many changes have been made in various data files, codes and program formats during 1978 additions to the LRIS; please refer to the Users Manual and associated Appendices for any detailed information. This report is intended to give an overview of the LRIS, with the Users Manual providing a step by step guide through the various computer programs written during its development. In addition, selected applications and analyses using LRIS data are described in this report, while others are discussed in the Appendices to the Users Manual.

INTRODUCTION

The Lake Erie Wastewater Management Study (LEWMS) has been underway in the Lake Erie Basin since 1974, under the direction of the Buffalo District, U.S. Army Corps of Engineers. Authorized by Public Law 92-500, Section 108(d), the study has focused on the input of pollutants to the lake from the surrounding drainage basin, some 23,000 square miles in the U.S. portion alone. The study has several objectives, discussed more fully in other reports (COE, 1975, 1978) but it would be accurate to state that the primary objective is to identify major sources of pollution to the lake and structure a plan by which water quality in Lake Erie can be restored and maintained. In the course of this objective, detailed analyses of pollutional sources and transport mechanisms must be made and methods of reducing the input of pollutants from these sources evaluated. The concept of a Lake Erie Comprehensive Basin Model has evolved, to serve as both an analytical tool and a land management planning framework. As the study moves into the broader planning phases, the study team and their co-operating agencies and consultants will need the capacity to weigh various management options, which for a study area of this magnitude and complexity can only be facilitated by a computer information system.

Purpose and Application of the LRIS

It was determined early in 1976 that a Land Resource Information System (LRIS) would be developed during Phase II of the LEWMS Study. This data base had to spatially express

the existing natural and cultural features within the Lake Erie Basin in a format that would satisfy the various study objectives. Within given time and funding constraints, the system has been designed to satisfy three basic needs of a LEWMS data base:

1. Coverage of the entire U.S. portion of the Lake Erie drainage basin.
2. Measurement of land features in a manner which will allow the generation of statistics for all desired combinations of features (co-occurences) which characterize a watershed, political division or planning unit.
3. Generation of output from the LRIS must meet the requirements of input parameters for all modelling components, including hydrologic, chemical and land use management modelling.

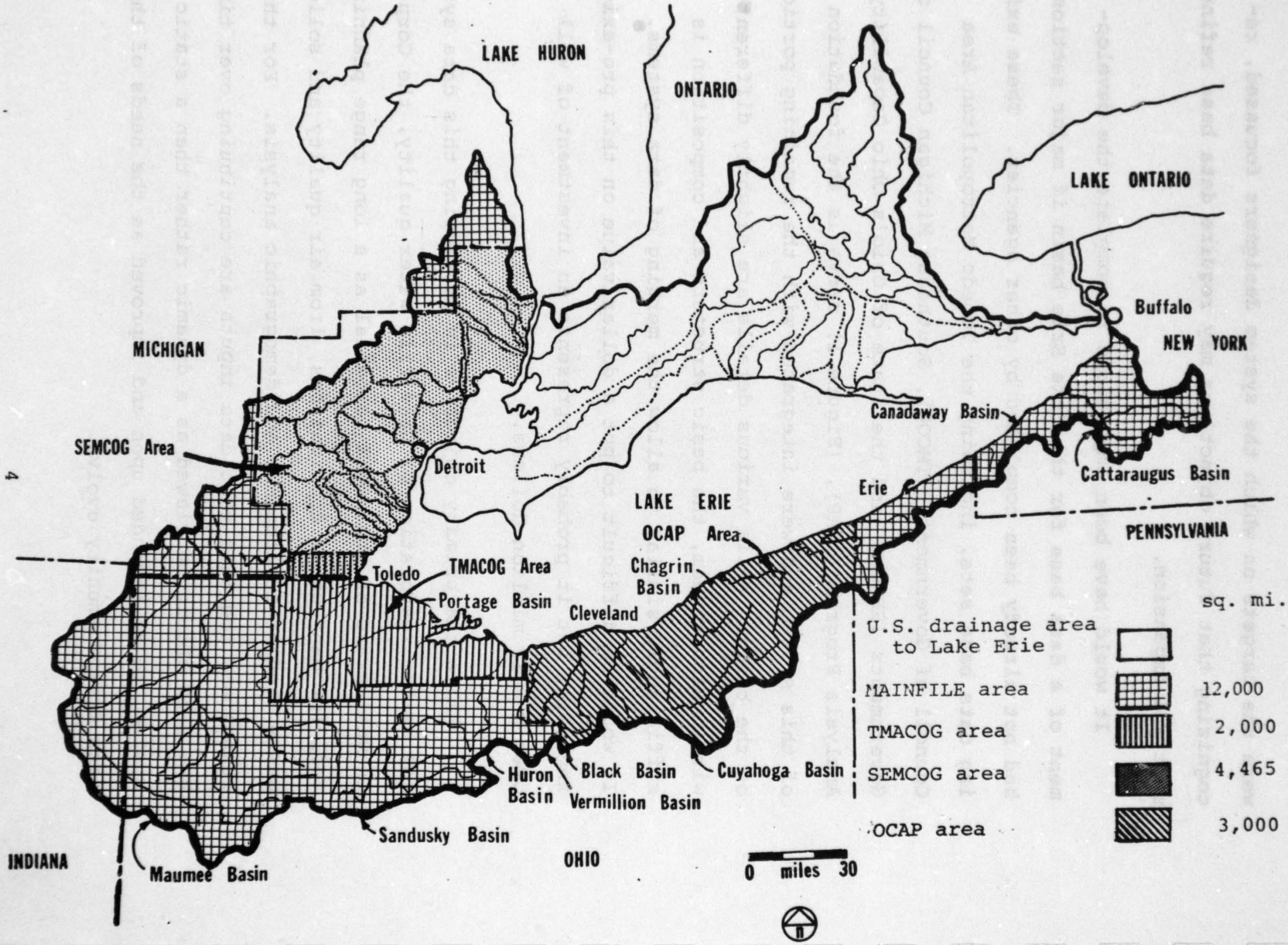
The option of developing the LRIS data base for only a portion of the Lake Erie Basin was considered, but it was felt the study demanded an evaluation of the total Lake basin initially, with more detailed studies of problem areas to follow if necessary. The concept of measuring land features with a technique that allows certain combinations of ingredients, such as urban land on impermeable soil, is a unique feature of the LRIS data base and is described more fully in a later section. Finally, the anticipated uses and needs of the data were prime considerations in the data system design, setting the level of detail and intensity of coverage criteria. The classic error of many studies is to gather either too much or too little data. The needs of analysis and planning models

were the targets on which the system designers focussed, recognizing that future objectives may require data base refinement and expansion.

It would have been impossible to complete the development of a data base for the Lake Erie basin if major sections had not already been completed by other agencies. These existing data base sets, including the Toledo Metropolitan Area Council of Governments (TMCOG), Southeast Michigan Council of Governments (SEMCOG) and the State of Ohio's Ohio Capability Analysis Program (OCAP), (Figure 1) serve as the foundation of this system and were integrated with the remaining portions of the basin. While various details are slightly different within each system, the basic structure and composition is sufficiently similar to allow the merging of data systems. It would be difficult to put a dollar value on this pre-existing data, but it probably represents an investment of well over a half million dollars.

While the primary objective in developing this data system is the restoration of Lake Erie water quality, the Corps is well aware of its broad potential as a long range planning tool for many other applications, from air quality and solid waste studies to economic and demographic analysis. For this reason and the fact that data inputs are continuing over time, the LRIS should be viewed as a dynamic rather than a static system, to be expanded upon and improved as the needs of the Lake Erie Community evolve.

Figure 1. Sources of Data for Land Resource Information System

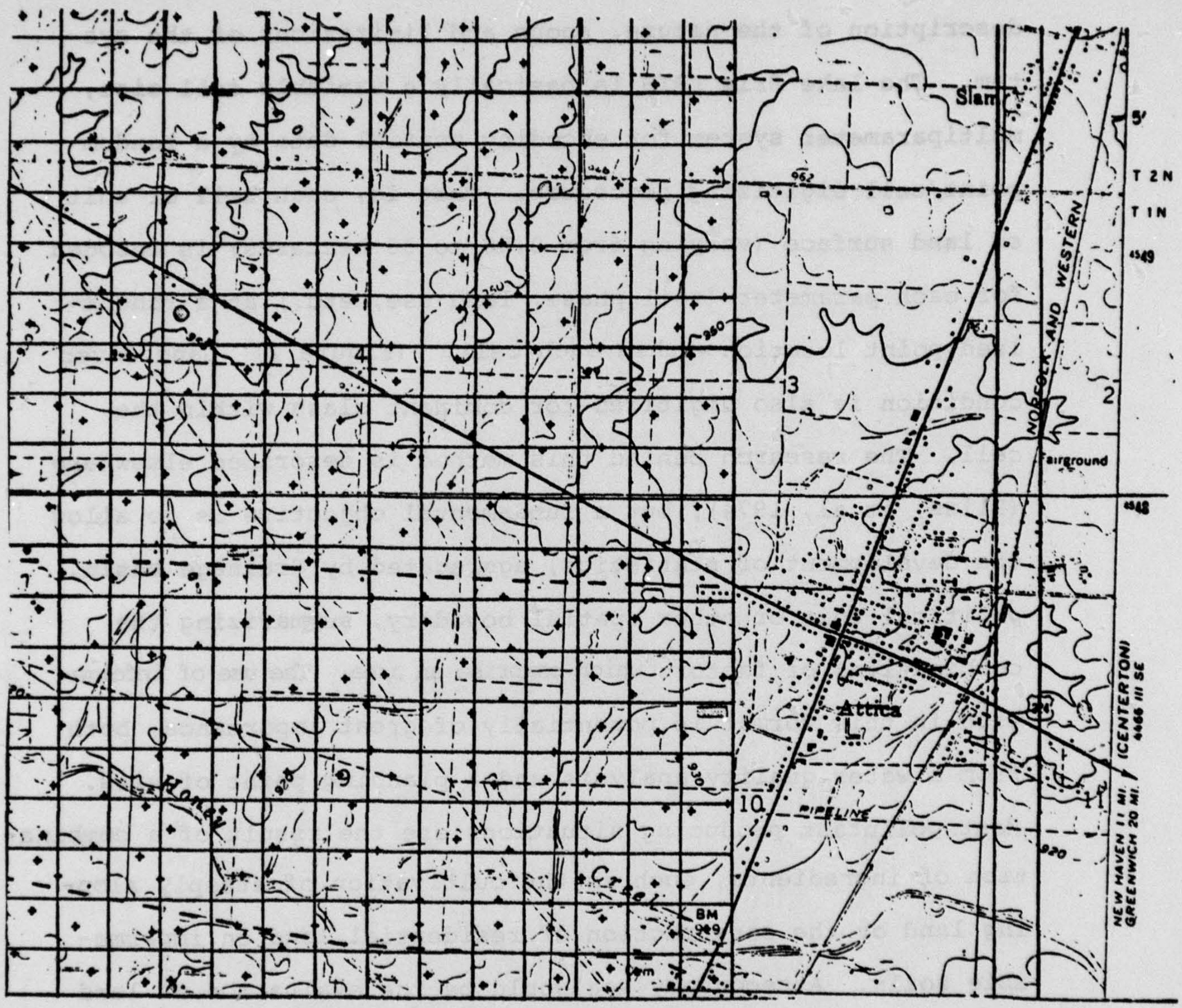


System Design - General Description

Before a detailed description of the various components of the LRIS data system, it is appropriate to give a general description of the nature, scope and limitations of the system. The Lake Erie LRIS is basically a variable cell size, multiparameter system for encoding spatial data by a random point/cell digitizing procedure. That is, each cell or unit of land surface (varying from 0.58 to 36 hectares) is encoded for each parameter (soil phase, land use, etc.) at a randomized point location within each cell. (Figure 2) Land Cover condition is also digitized for dominant class within the cell. The research behind this method is described elsewhere (Bliss, et al, 1974), but a fundamental objective is to allow the development of statistics, aggregated by drainage basin, political unit or other spatial boundary, summarizing the combinations of factors which comprise an area. The use of information in this format is potentially of great importance, both from a water quality analysis and a planning point of view. Most pollutant producing situations are the result of a combination of ingredients, such as the cultivation of steeply sloping land or the construction of residential land on impermeable soils. A secondary use would be the evaluation of land resources for local or regional planning purposes, from selecting the best open space land to chosing a land fill site. Under the LEWMS Study, its primary purpose will be to enable the evaluation of diffuse or non-point pollutant production potential into Lake Erie tributary basins.

The LRIS includes information on the two principal land-related factors: LAND USE and SOILS. It also provides two

Figure 2. Example of Cell-Point Data Coding System (Honey Creek Basin)



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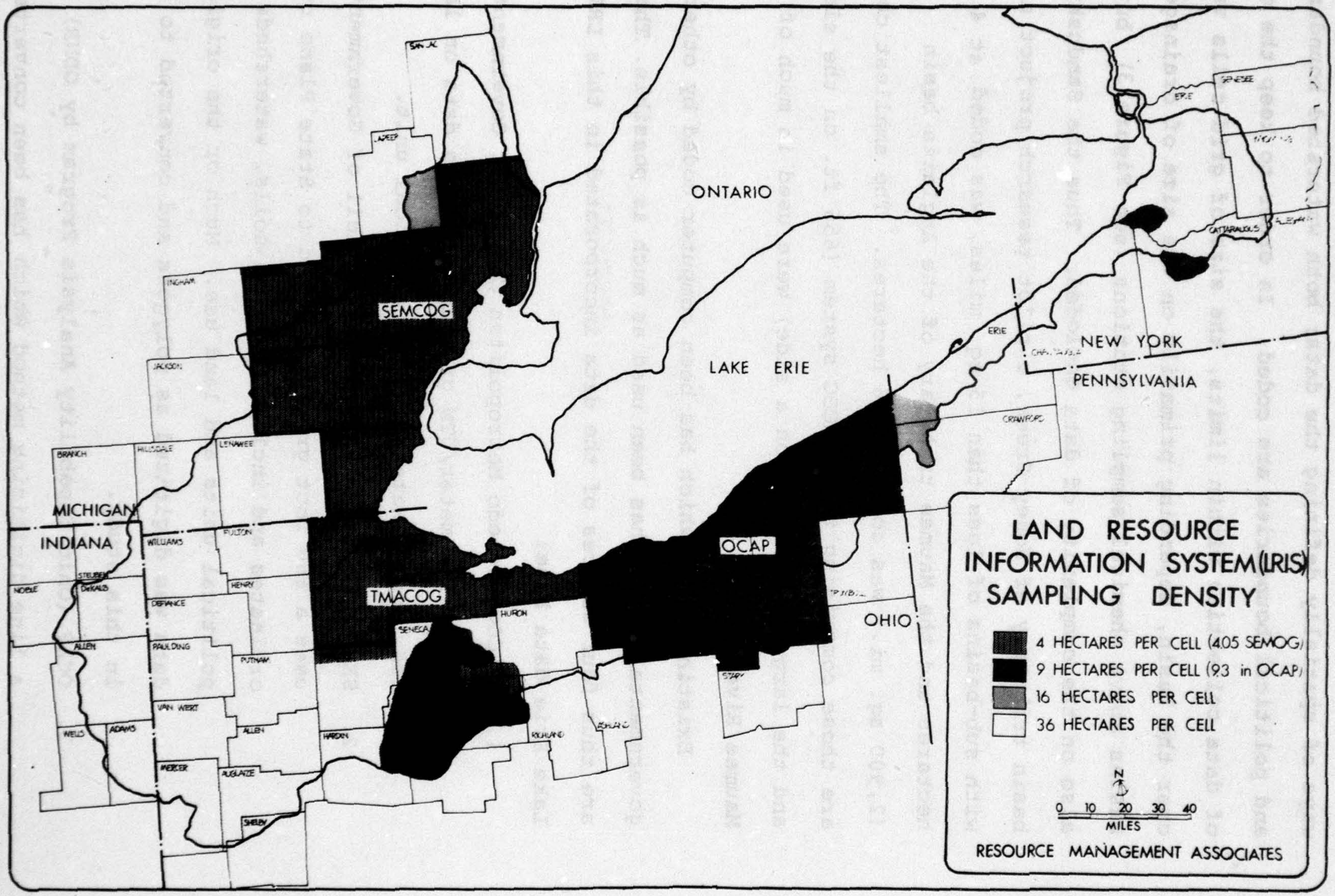
ways of spatially defining the data; both watershed boundaries and political boundaries are coded. In order to keep the costs of data collection within limits, the size of grid cells varies over the basin, depending primarily on the size of drainage basins above chemical sampling stations (see Figure 3) but also on the complexity of data encloded. Thus the Sandusky basin tributary of Honey Creek, a pilot research project area with sub-basins of less than 15 sq. miles, was coded at 4 hectares and the Maumee tributary of the Auglaize basin (2,900 sq. mi.) was coded at 36 hectares. The smallest cells are those comprising the TMACOG system (656 ft. on the side) and the largest (1970 ft. on a side) were used in much of the Maumee River basin.

Existing data, which has been computer coded by other governmental units, has been used as much as possible. There are thus four sources of the data incorporated in this LRIS Lake Erie data base:

1. TMACOG (Toledo Metropolitan Council of Governments) uses a 200 meter/UTM grid and includes data on land use, soils, watershed, and political unit.
2. SEMCOG (South East Michigan Council of Governments) uses a 660 foot grid referenced to State Plane coordinates and includes data on soils, watersheds, political units and land use. Much or the original data was digitized as polygons and converted to cells in this study.
3. OCAP (Ohio Capability Analysis Program by ODNR) uses a line digitizing method which has been converted to

Figure 3. Cell Size for Sampling



approximately a 9 hectare cell. It is not tied directly to any coordinate system, but rather orientation is based on latitude. Data is included on land use, soils, watershed, and political unit.

4. COE Main File (Corps of Engineers), uses a variable cell size with either 200, 300, 400 or 600 meter cells. Reference is to the UTM coordinate system. Data is included on land use, soils, watershed, and political unit.

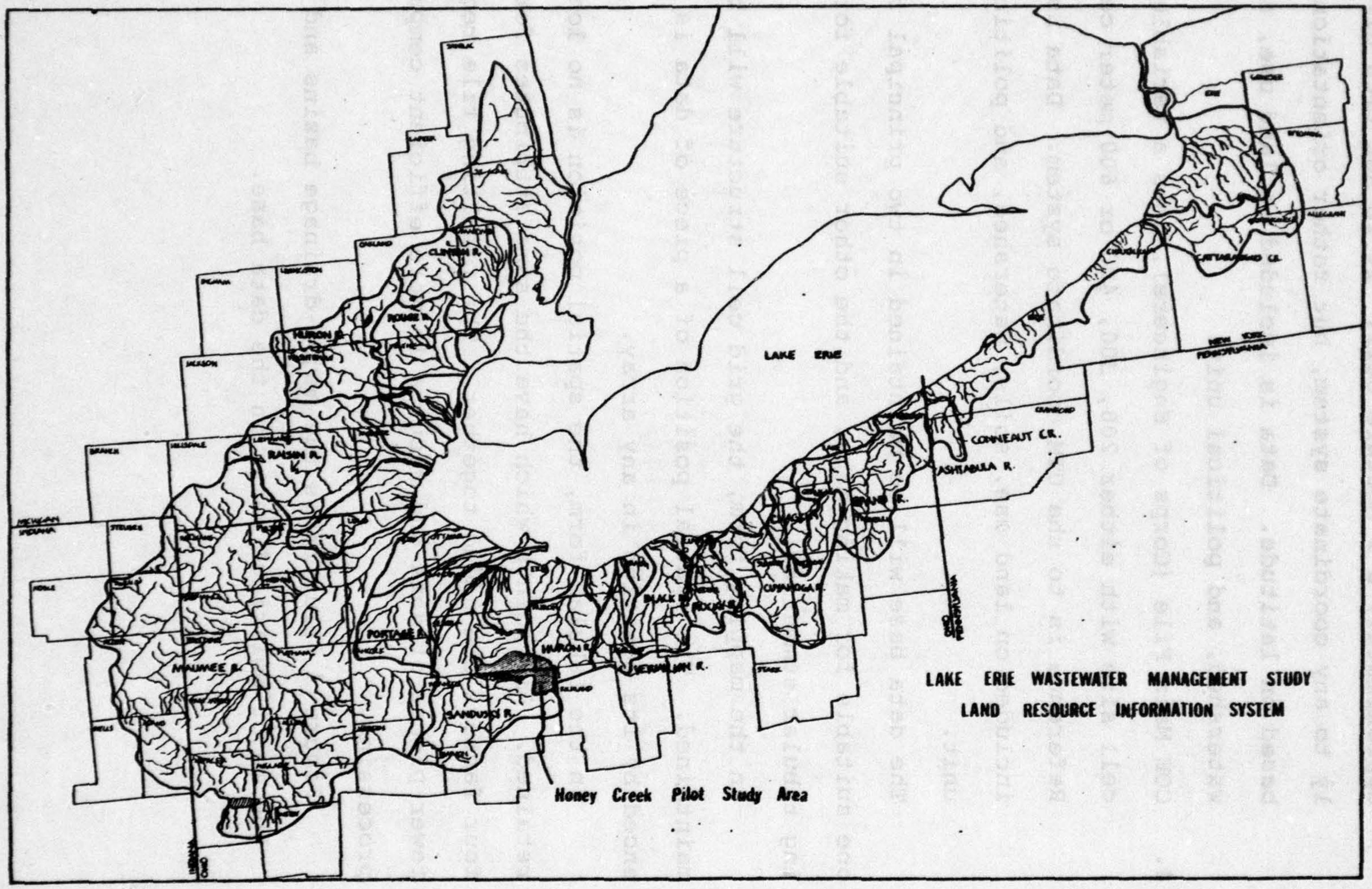
The data base will be maintained in two principal forms: one suitable for making maps, and the other suitable for making tabular summaries.

In the mapping form, the grid cell structure will be maintained. The spatial position of a piece of data is referenced by its position in any array.

In the tabular form, the spatial position is no longer retained. All points which have the same attributes for all four factors are added together. The resulting file requires fewer pieces of data and results in more efficient computer processing.

Figure 4 illustrates the major drainage basins and the major political units in the data base.

Figure 4. Drainage Basins and Political Units in LRIS



ELEMENTS OF DATA BASE

Soils and Attributes File

Probably the most important natural feature determining the amount of sediment and runoff generated by agricultural and other land use activities is the soil series on which these activities are located. Soils information is therefore the most critical element of the LRIS. Soil series properties will be used to develop the chemical transport model and to determine values for parameters of the hydrologic model.

While the above uses suggest the importance of soils information in the analytical tasks of LEWMS, this information will play an equally important role in the planning (management modelling) tasks. Selection of the best farm management alternatives to reduce sediment (and therefore, phosphorus) generation is largely a function of the natural features (particularly soil and slope) of the agricultural site. Before any set of farm management alternatives can be run through the management model, the desired spatial extent of those alternatives must be determined. This will be done by comparing the existing management practices for any site with the best management practices as suggested by the natural features. Where existing practices fall short of best recommended practices, a change can be made for that farm, watershed, etc. and run through the model to predict the resultant on-land and in-lake effects.

Soil Conservation Service (SCS) Soil Survey information is the primary data source for soil series information. The SCS maps soil series information on a county basis. Figure 4 shows the 63 counties in New York, Pennsylvania, Ohio, Indiana and Michigan that are partially or totally within the Lake Erie basin. The status of SCS mapping in these counties is reported in the User's Manual. Approximately half of the country surveys are in published form, but nearly all of the remainder are underway. In some portions of the lake basin, soil series information could not be digitized directly on a point by point basis. This limitation of available data was mitigated in three ways:

1) The sampling test basins selected to develop the chemical transport model and to calibrate the chemical transport and hydrologic models were not located within these data-limited areas;
2) Incomplete information has been related to more complete soil series information in neighboring counties to fill in some gaps during subsequent updating of the file;
3) Arrangements were made with some SCS offices to complete series mapping in small areas.

Table 1 illustrates the type of information recorded for each soil series in the soils file. The soil properties are taken directly from the SCS surveys, while the "interpretive" information has been developed in this study.

Table 1. Sample of the Information in the LRIS Soils Property File for Each Soil Series

Directly Recorded from the SCS Soil Survey

1. Parent material
2. Drainage class
3. Permeability rate
4. Depth to seasonal high water table
5. Percent of fine particles (clay)
6. Depth to bedrock
7. Available moisture capacity
8. Agriculture capability class
9. Erosion potential "K" factor
10. Texture

Interpreted from Soil Series Properties

1. Physiographic region
2. Suitability for erosion prevention management practices.

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Interpretative information such as physiographic region or management practice suitability will be important in all modelling phases of LEWMS. Sediment generation from agricultural activities will probably vary as a function of physiographic region, for example. If this relationship can be adequately expressed, it may contribute to a better calibration of the hydrologic and chemical models during the analytical tasks. As was mentioned above, a determination of the appropriate set of management practice alternatives for different areas within the lake basin will in large part be soil series dependent; hence, interpretations of the soils data for management practice alternatives will be an integral part of the management modelling tasks.

Soil information in the LRIS is found in three parts. First, the digitized soils data file stores a soil phase code at each point/cell in the study area. Soil phases are the subdivisons of soil series that the SCS maps in each county. To facilitate processing of this information, LRIS has converted the alphanumeric soil phase symbols coded from the maps into a set of numeric phase codes in the data base. These numeric codes are used to access the second part of the LRIS soils data -- the phase file.

The phase file stores some general information about each phase number encountered in the digitized soil data file, as well as the information necessary to access the detailed soil properties for each phase. Table 2 is a list of the information in the phase file.

Table 2. Information in the LRIS Phase File

1. RMA phase #.
2. SCS soil series name.
3. SCS soil phase mapping symbol.
4. Soil texture.
5. County in which the phase is found.
6. Slope of the soil phase.
7. Reference numbers to soil property file.
8. Additional remarks helpful to property assignment.

The third part of the soils information in the LRIS is the national property file. This file contains a full set of properties on each soil phase which was coded in the digitized soil file. The properties for each soil were compiled by the SCS on computer tape in Lincoln, Nebraska from test data collected locally. These properties refer to a soil series wherever it is mapped in the country; hence, the LRIS scil property file is used to identify the properties of a soil phase in every county within the Lake Erie basin in which it was found. Some of the many properties found in the property file were listed above in Table 1.

The Users Manual contains a full list of properties plus the technical information necessary to both read the phase and national property files and to associate this information with the digitized soils file.

Shortened Soils Property File

The soil phase file, as discussed in the preceding section, was developed from the digitized soils data for each county in the LRIS. Thus the same phase could occur in several counties and be listed as separate records in the phase file. For example, "Hoytville clay, 0 to 2%" is present in several counties and appears in the phase file several times. By sorting the file on "name-texture-slope", the 8,700 records were reduced to a shortened file of 3,131 unique phases. These 3,131 records were called "pointers", because they point to a unique set of soil properties in the soil properties file (S-5).

The full S-5 soils property file, in turn, contains a great deal of information not necessary for the desired work task of analysis, table or map production anticipated in this study. Thus a shorter property file was felt necessary and developed by unique phase, or pointer. This short form of the soils property file was built upon and modified over a period of months to include a variety of information, such as special codes for drainage class and soil management group (SMG), as well as the calculated length-slope factor (LSFAC) and other new data. The Users Manual contains the index for this file record, which has become one of the key computer files for much of the work described in the following sections. The development of this file required numerous decisions with respect to the various soils properties, with a great deal of guidance provided by SCS soils scientists in the Lake Erie Basin and Computer experts at the Statistical Laboratory, Ames, Iowa. The Users Manual also lists the various programs which have modified the short property file during development of the LRIS.

Land Cover File

Photointerpretation

The emphasis on diffuse sources of phosphorus generation in the LEWMS Study dictated that the LRIS describe existing land use and in particular, agricultural land use, throughout the lake basin.

Photointerpretation of high altitude infrared photography was the primary data source to digitize land use information for the LRIS. In June, 1976 color infrared photography covering the Sandusky Basin and contiguous watersheds (approximately 2000 sq. miles), was photographed by NASA Lewis, Cleveland, at a 1:70,000 scale. This data was photointerpreted using a relatively dense grid of 4 hectare cells (200 meters per side), for portions of the basin and 9 hectare cells for the balance. The Honey Creek Basin, (Fig. 3), 177 sq. miles of the Sandusky Basin above Freemont was done as a pilot effort at the 4 hectare density (11,483 cells), and the balance of the area finished primarily at the 9 ha density. Relatively dense sampling within the Sandusky Basin was necessary for development and calibration of the hydrologic and chemical transport models.

The balance of the Lake basin has also been photographed (color IR) by NASA, Ames, Iowa at a 1:120,000 scale. The land use photointrepretation of this data was done at varying densities, either 16 or 36 hectare cells.

Land Use/Land Cover Coding Scheme

Land use/cover information is included in the LRIS data base for all areas of the Lake Erie drainage basin. While the coding scheme used to digitize cover information in the TMACOG file and CORPS main file areas was nearly identical, the OCAP coding scheme was significantly different, as was the SEMCOG scheme. A new coding scheme which is consistent across all four data sources has been created.

Since the codes for the TMACOG and main file schemes were so similar, (Haack, 1977) they have been used as the base and the OCAP coding scheme was "fit" into them. Two simple rules were sufficient to fit the OCAP codes:

1. When an OCAP category matched closely with an ERIM category, the OCAP code was simply replaced by the ERIM code in the data base.
2. When an OCAP category did not match closely enough with an ERIM category, a new code member was added to the ERIM coding scheme and the OCAP code was assigned this number. If a new code number was nesessary, the number chosen fell as closely within ERIM's overall coding structure as was possible.

Table 3 lists the final categories and land use code numbers used in the data base. The Users Manual contains code numbers in the four separate data sources which formed these categories and codes. The OCAP data actually used two separate coding schemes, one for land use and one for land cover. A county was coded either for land use or land cover, but not both.

Table 3. Land Use Code Summary

Final LRIS	Land Use Description
8	Commercial-industrial, undifferentiated
9	Mixed Urban or Builtup land
10	Residential, undifferentiated
11	Residential, Single Family: detached houses on individual lots in an urban, suburban, strip or cluster development area.
12	Residential, multiple Family: Apartments, Townhouses, or row houses.
13	Mobile Home: large trailer park or single unit
14	Commercial and services: central business districts, shopping centers, commercial strips and sales or service facilities.
15	Industrial: light to heavy manufacturing, mills, plants.
16	Institutional: Educational, religious, health, correctional and military facilities, including all grounds.
17	Extractive: sand and gravel pits, quarries, wells and mines.
18	Open Space: Golf courses, parks, cemeteries and undeveloped urban land.
19	Other Urban: Urban areas of less intensive or nonconforming uses which are not covered above, such as land fill areas.
20	Disrupted Cropland: Cropland with major irregular patterns of unvegetated areas.
21	Cropland, Undifferentiated: Land used to produce agricultural crops.
22	Truck Crops: Large agricultural fields.
23	Orchards and Bush-Fruit areas.

Table 3. Continued

Final LRIS	Land Use Description
24	Horticulture: includes nurseries, ornamental shrubbery, floricultural areas, and seed-and-sod areas.
25	Old Field Vegetation: farm land not currently being used for production.
26	Feedlots: chiefly beef cattle feedlots and large poultry farms.
27	Farmsteads: land used for buildings associated with agricultural production.
28	Other Agricultural Land: agricultural land not included in the preceding categories.
29	Row Crop: Corn, soybeans, etc.
30	Field Crop: Small grains, cover crops.
31	Brushland: Land covered with woody vegetation.
32	Strip Cropping: Alternate crop types in strip pattern.
41	Deciduous Forest: deciduous forest include all forested areas in which the trees are predominantly hardwoods.
42	Coniferous Forest: coniferous forest includes all forested areas in which the trees are predominantly those with needle foliage.
43	Mixed Forest: Mixed forest land includes all forested areas where both deciduous and coniferous trees are growing and neither predominates.

Table 3. Continued

Final LRIS	Land Use Description
44	Forest or grassland: undif.
45	Forest: undif., type not determined
51	Rivers and Streams: includes rivers, streams, creeks, canals, drains and other linear bodies of water.
52	Lakes: Lakes are non-linear water bodies, excluding reservoirs.
53	Reservoirs: Reservoirs are artifical impoundments of water.
54	Bays and Estuaries
55	Water or Marshland: undif.
61	Wetland, Forested: Seasonally flooded basins and flats, meadows, marshes and bogs.
62	Wetlands, Non-Forested: Same as above but less than 25% tree cover.
71	Beaches,Mudflats, unvegetated areas: the sloping accumulations of sand and gravel along shorelines.
72	Construction activity: Land which is barren due to clearing operations associated with construction activity.
73	Sandy areas other than beach.
74	Bare exposed rock.
75	Barren/abondoned mines, quarries.
76	Exposed rock/sandy areas: undif.
81	Improved roads: all paved roads and highways.

Table 3. Continued

Final LRIS	Land Use Description
82	Unimproved Roads: Gravel, oiled and dirt roads.
83	Railroads: All facilities connected with rail transportation, including rights-of-way.
84	Airport: All facilities directly connected with airports.
85	Utilities: Areas associated with the transport of gas, oil, water or electricity.
86	Shipping Ports: Facilities connected with commercial shipping transportation.
87	Utility and Rail Row: Undif. either 83 or 85, above.
88	Transportation: undif.

SEMCOG Land Use Conversion

As one of the tasks necessary to integrate the SEMCOG data into the LRIS files, the land use information for the seven county area had to be converted to a compatible data structure. The original land use file digitized for SEMCOG consists of over 120,000 polygons, comprised of some 2.7 million X-Y pairs or coordinates. These had to be converted to the 10 acre grid cell structure of the other SEMCOG digital data. A program was written overlaying the two digital files and recording the polygon which covered the midpoint of every 10 acre cell in the spatial data base. Since about 30% of the polygons covered land areas of 1 acre or less and another 30%(approx.) covered areas between 1 and 5 acres, not all polygons were recorded in cells of the new data file. Approximately 28% of the total polygons were eliminated in this fashion. Because initial tests indicated some encoding errors in the polygon file, the conversion program included a geometric test to identify and correct incomplete polygons. Of the original number of polygons, 466 were found to be in error and all but 24 were corrected. As stated above, the conversion from polygons to cells resulted in a 28% reduction of polygons. The final total was thus 86,500. As a matter of interest, the largest single polygon consisted of 630 X-Y pairs.

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Political Boundaries File

A political jurisdiction code is included for every point in the data base. The code indicates both the county and minor civil division (e.g., township), and the codes can be aggregated to a State coding scheme. The coding scheme used for all four data sources is straightforward. First, each of the 62 counties with area within the Lake Erie basin was assigned a two digit identification number (see Table 4). Next, all the municipalities in each county were alphabetized and assigned consecutive 2 digit numbers starting with the number one. The county identification code number was then prefixed to each municipality code number within the county to form the four digit political jurisdiction code numbers found in the data file.

To access data for a specific municipality the four digit code must be used. If data for a specific county is desired, the last two digits can be ignored. A complete list of the political jurisdiction code "directory" file, along with the actual data files to interpret them, is included in the Users Manual.

Table 4. County Codes for the Lake Erie LRIS

1. Monroe
2. Crawford, Ohio
3. Seneca
4. Huron
5. Ottawa
6. Sandusky
7. Erie, Ohio
8. Wood
9. Lucas
10. Hancock
11. Wyandot
12. Hardin
13. Marion
14. Richland
15. Henry
16. Ashland
17. Medina
18. Cuyahoga
19. Summit
20. Lake
21. Geauga
22. Portage
23. Stark
24. Ashtabula
25. Trumbull
26. Erie, Pa.
27. Crawford, PA.
28. Chautaugua
29. Erie, N.Y.
30. Cattaraugus
31. Wyoming
32. Sanilac
33. Lapeer
34. St. Clair
35. Ingham
36. Livingston
37. Oakland
38. Macomb
39. Jackson
40. Washtenaw
41. Wayne
42. Branch
43. Hillsdale
44. Lenawee
45. Steuben
46. Williams
47. Fulton
48. Noble
49. DeKalb
50. Defiance
51. Lorain
52. Allen, In.
53. Paulding
54. Putnam
55. Wells
56. Adams
57. VanWert
58. Allen, Ohio
59. Mercer
60. Auglaize
61. Shelby

63. Alleghany

Drainage Basin File

The primary unit of analysis for the LEWMS Program is the watershed or sub-watershed. The LRIS, therefore, must be capable of aggregating data at this level. Watershed and sub-watershed boundaries have been digitized in addition to the land and soil characteristics for each point sampled. In this manner, any hydrologic unit, from a sub-watershed to a larger river basin of which it is a part, can be aggregated for analysis or modelling.

The drainage sub-basins were defined on 7½ minute quad sheets and this set of watershed boundary maps comprised the source of data for basin digitization. Once the boundaries were traced onto a set of topographic maps, they were coded and digitized. In addition, the chemical sampling stations monitored during 1977 were located on these quads to facilitate the summarization of factors for the basins subtended by the stations.

For the SEMCOG region, drainage basins were originally digitized as polygons under a prior study and converted to a cell structure under this study. For this portion of the LRIS, the drainage basins were generally much smaller in size and so were aggregated to larger sub-basins in the Users Manual. For the other areas, the unique raw basin codes are listed. The Users Manual also contains the information necessary to aggregate sub-basins to drainage areas subtended by sampling stations.

STRUCTURE OF DATA FILE

Spatial Data File

Although the UTM grids used by TMACOG and the COE Main File are compatible with each other, the grids from OCAP and SEMCOG are not compatible with these or with each other. To force one grid structure into the specifications of another with different cell size and alignment can result in a severe degrading of the quality of the data. In order to avoid this loss of the quality of the data, the mapping files as compiled consist of four parts:

Part I: COE Main File; UTM Zone 16

Part II: COE Main File and TMACOG; UTM Zone 17

Part III: SEMCOG

Part IV: OCAP

If maps are desired of the entire study area, or of pieces of the study area which overlap two or more of these parts, the maps will be plotted separately for each of the parts, and then spliced together manually. Appropriate reference points will be plotted so that the splicing may be done accurately. (The 4 "parts" of the data base are illustrated in Figure 1).

Although it might be more aesthetically pleasing to see a map with all the grid cells in a single alignment, the loss of the accuracy inherent in the original data would be too great to justify this slight aesthetic improvement.

Main File split plotting will occur at the 84 degree meridan, which divides UTM Zone 16 form UTM Zone 17, since the cells in the two zones have different alignment.

Data Sections

For preliminary manipulation of the data, and for storage in the mapping file, the data is split into sections. Each section will be stored as a separate data set in the computer. These sections are designed to optimize the amount of data to be processed at any one time. If the sections are too large, then it is necessary to process large amounts of data in order to correct or retrieve data for a specific small area. If the sections are too small, then a large number of sections will be required to process large geographic areas.

For this study, areas covering between 200,000 and 300,000 hectares were selected as optimal, although there may be substantial deviations from this optimum in order to accomodate the irregular shape of the study area with the least waste of computer storage.

The sections represent subdivisions of the "parts" which were outlined above. Thus, two groups of sections will be applicable for the areas covered by the COE Main File and TMACOG, a third group for SEMCOG, and a fourth group for OCAP. Figures 5 and 6 show the coverage and identification for each data section as it relates to the counties and drainage basins of the LEWMS study area. Tables in the Users Manual cross-reference the data section to the UTM coordinate system, the four data sources, the political units and the major basins, respectively.

For the COE Main File and TMACOG, an additional level of grid structure is necessary to accomodate varying densities. These will be subdivisions of sections and will be identified as regions. A region is 6000 meters on a side. The regions formed a basis for organizing the initial data collection. They were always coded at a uniform density.

Figure 5. Data Section - County Guide Map

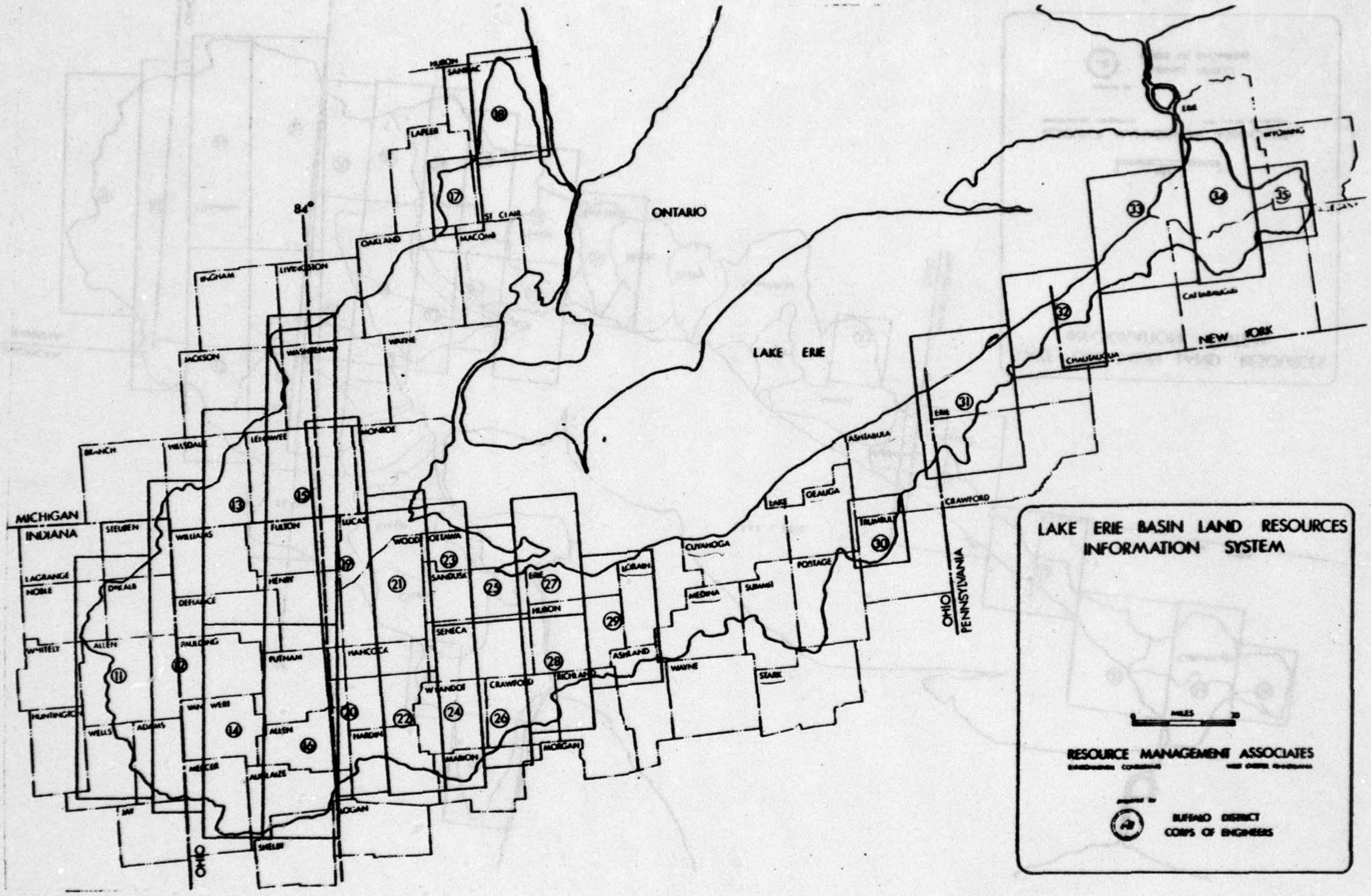
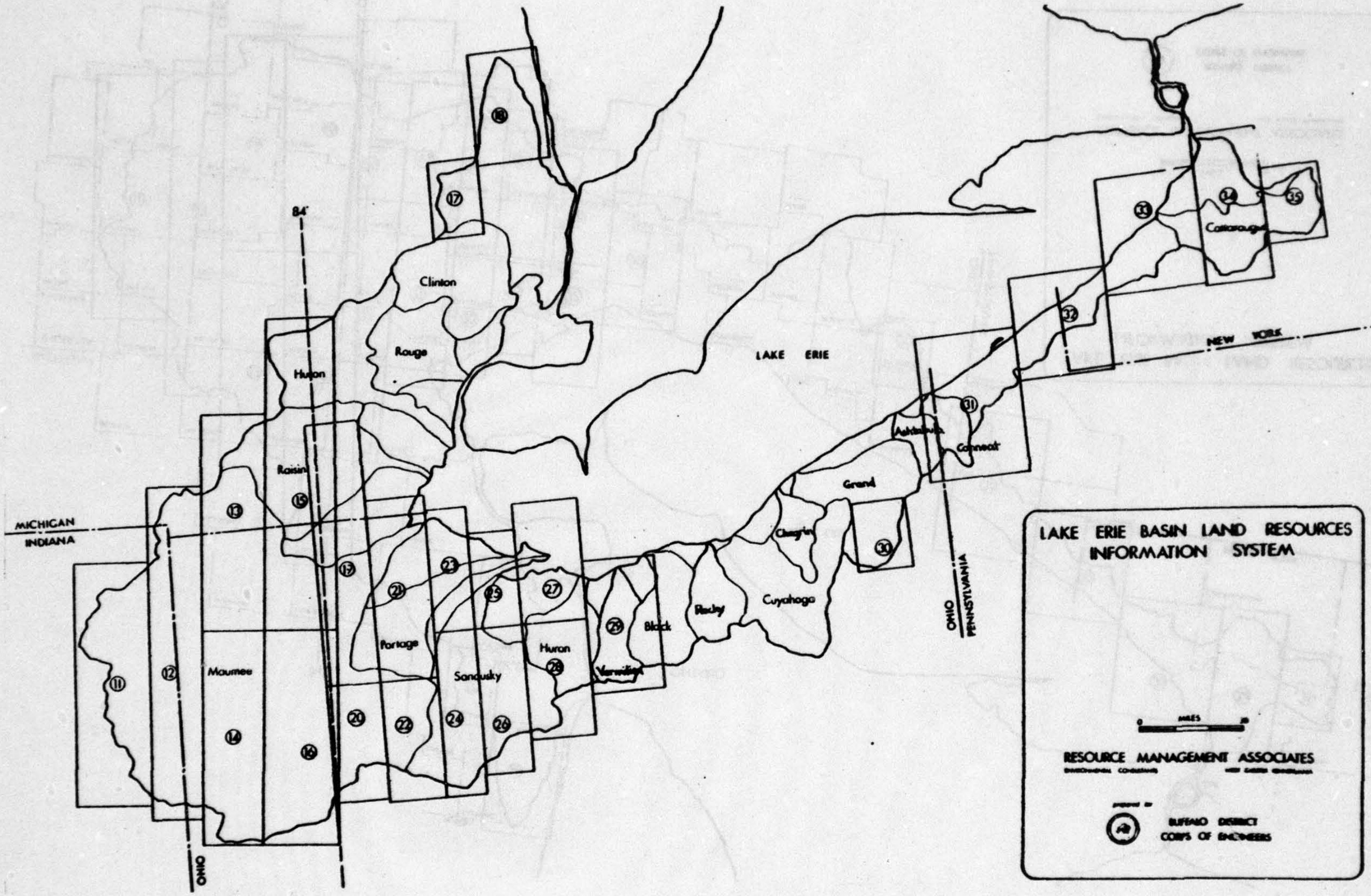


Figure 6. Data Section - Watershed Guide Map



Thus, if 200 meter cells were being coded, an entire 6000 meter region would be coded with 200 meter cells. If an adjacent region were being coded with 600 meter cells, then the entire region would be coded with 600 meter cells.

The data sets storing the sections are structured so that they take advantage of the savings in processing which are possible when only a small number of points were coded, and still have the capability to deal efficiently with the regions in which large numbers of points were coded. The first data records of the section include information on its location, its dimensions, and the density of each of the regions within it. This initial information is used by the program in order to properly read the subsequent data in the data set.

There are two items to note concerning making the TMACOG data compatible with the COE Main File data. First, the initial data collection by TMACOG made use of 5000 meter regions rather than 6000 meter regions. Since the size and alignment of cells is the same for the two studies, there is no problem in merging the two data sets. However, the random (i.e., systematic unaligned) point location within the TMACOG cells cannot be reconstructed using the same array of points as is used for the COE Main File. Since reconstructing the original point location is not envisioned at any point in this project, no harm is done by obscuring these original point locations. Second, at the boundary between the TMACOG and the COE Main File coding, a change in coding density will occur. In order to keep the regions of uniform density, the 400 meter or 600

meter cells of the COE Main File portion of the region will be converted to the 200 meter basis used in TMACOG. Some portions of the COE Main File (i.e., the Sandusky basin) were coded with 300 meter (9 hectare) cells. Where regions coded at this density overlap into the TMACOG area, the TMACOG data will be converted from the 200 to the 300 meter basis. Although this represents some loss of information, the number of points is small. The additional programming effort necessary to use the data with more than one density in a region would not justify the small loss of accuracy.

LRIS DATA OUTPUTS AND PRODUCTS

Counted Files

Initial summaries of data represent a quantitative description of the soils, land uses and their cooccurrences within the various basins. This means that the area and/or percent of a basin falling into each soil, land use and soil/land use category was counted. Since the results of ongoing land use and water quality programs might suggest land use management policies which could be better expressed by political planning units, a data file counting soils and land use area by municipalities was also provided.

These files (whose structures are described below) represent the most basic expression of the data for modelling and other analysis beyond its raw form. A count of the area (in hectares) of each cooccurrence of the soil phases and study area is stored. But before these "counted" files are useful for analysis, the individual codes must be aggregated into meaningful groupings. In terms of hydrology/stream chemistry modelling, the sub-basin codes must be aggregated to sampling station drainage areas for which flow and chemistry data are available. For management modelling, it is felt that counties might provide a useful aggregation of political boundary data. Thus a 4-way counted file is provided in the LRIS, by basin, county, land use and soils, to allow any necessary aggregation to be made.

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It should be noted that soil and land use codes were also aggregated to meaningful groupings before data analysis. However, there are many different aggregations which are potentially useful. The development of computer files with such aggregations are detailed in the Users Manual, but it should be recognized that as other applications of the LRIS are made, new counted data files will be created.

In describing a land area, be it a watershed, a township or some other planning unit, it is frequently beneficial to summarize the composition of a descriptive factor, such as land use or soils. The counted files discussed previously do this for major sub-divisions of the LRIS by counting the number of occurrences or point/cells in a given area. Most natural processes, however, are a function of combinations of ingredients or land factors. For example, the runoff or hydrologic response of a watershed is dependent not only on the type of soils in the basin, but also on what land uses occur on the various soils, determining the degree of vegetative cover or impreviousness. Other factors, such as the slope of land or degree of relief, also enter into the picture, especially when the question of sediment production by soil erosion is raised. Man's use of land also reflects the consideration of combinations of factors, from cultivation to construction. Thus it is important that the LRIS have the capacity to quantify selected combinations of land resource factors, or "co-occurrences", as descriptive statistics of any land area in the data base.

In prior studies (RMA, 1975; 1976; 1978) such statistics were used in a variety of ways for analysis of land use-water quality relationships, for mathematical modeling, for zoning and ordinance drafting, comprehensive plan formulation, land treatment of wastewater effluent and many other planning applications. Special software was written for each application or study to produce tabular data summarizing the selected factors one with another (called a two-way count) or grouped by addi-

tional factor combinations (three or four way counts). Such aggregations increased in complexity with additional dimensions in the array to a point of diminishing returns. That is, for comparative purposes among data sets or land areas, cooccurrences of more than three dimensions were generally difficult to comprehend. On the other hand, for screening procedures or selection of specific land areas, such as landfill sites or high density residential land, co-occurrences of six factors or more have frequently been used.

For a general data base such as the LRIS, whose use and application are only beginning, it was felt that a more general co-occurrence file and table production system be developed, to facilitate a "hands on" capability by potential system users. For this reason, a generally available statistical package, the Statistical Package for the Social Sciences (SPSS, 1974), was used for both table production of co-occurrence summaries and the multivariate regression analysis discussed in the Users Manual section. This procedure required the creation of a data set from the counted LRIS files in which each unique combination of basin-land use-pointer (unique soil phase) became a record, including its count or acreage. From the pointer file of unique phases (there are 3,131), selected properties were included in this "SPSS Raw Data" file, such as texture, minimum permeability by horizon, drainage class, slope, intrinsic erodability and land capability class. This large file (over 17,000 records in the main file portion alone) was then used to create statistical summaries for each variable, with selected statistics such as relative, adjusted or cumulative fre-

quencies and co-occurrence tables. Since this statistical package considers each record as a sample, the fact that the records are of different size (area) required a weighing procedure to calculate the correct magnitude of any co-occurrence. The area of each co-occurrence was multiplied by the variables in question to obtain summary tables of the type shown in Tables 5 and 6. Table 5 shows the breakdown of slope categories, from "less than 0.2%" to "13% or greater" that occur in major basins. For example, the first basin listed, the Maumee River at Waterville, Ohio, contains 2,262 square miles of land whose slope is less than 0.2%. This represents 42.7% of all the measured land in the basin (missing data is not included), and 59.3% of all the land in this slope category for the main file. Overall, the co-occurrence of this slope category in the Maumee comprise 18.4% of all land area in the main file data set, summarized at the lower right hand corner.

Table 6 summaries the co-occurrence of two other factors, land use and soil texture, as they exist within basin no. 34, the Cattaraugus River , Gowanda, New York. This table shows that cropland in the basin occurring on loam soil is 22 sq. miles, or 55.7% of all loam soil is in cropland, which is 12.7% of all cropland and 5.4% of all land. Note that this table is considered a 3-way co-occurrence because two variables, texture and land use, are sorted by a third variable, drainage basin.

Table 5. Two-way Co-occurrence

COOCCURRENCE TABLES 11/07/78 PAGE 2

FILE MF1 (CREATION DATE = 11/07/78) BUFFALO DIST.,COE LAKE ERIE LRIS

* * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * *

BASIN SAMPLING STATION BASIN BY SLOPE DON URBAN SLOPE VALUE

* PAGE 1 OF 6

BASIN	COUNT / ROW PCT / COL PCT / TOT PCT	SLOPE LESSTHAN 0.2 (0.2)	0.5 (0.5)	1.0 (1.0)	2.0 (2.0)	3-5 (4.0)	6-8 (7.0)	9-11 (10.0)	12-14 (13.0)	15-17 (16.0)	18 OR GREATER (18.0)	ROW TOTAL
1. MAUMEE @ WATERVI	COUNT	2262	524	992	81	1259	7	124	11	26	14	5299
	ROW PCT	42.7	9.9	18.7	1.5	23.8	0.1	2.3	0.2	0.5	0.3	43.1
	COL PCT	59.3	44.6	37.8	10.2	49.5	1.2	25.5	53.4	54.2	7.5	
	TOT PCT	18.4	4.3	8.1	0.7	10.2	0.1	1.0	0.1	0.2	0.1	
2. PORTAGE @ WOODV	COUNT	221	54	6	5	91	6	3	0	0	0	386
	ROW PCT	57.2	13.9	1.5	1.4	23.5	1.7	0.9	0.0	0.0	0.0	3.1
	COL PCT	5.8	4.6	0.2	0.7	3.6	1.0	0.7	0.5	0.0	0.0	
	TOT PCT	1.8	0.4	0.0	0.0	0.7	0.1	0.0	0.0	0.0	0.0	
3. SANDUSKY @ FRM	COUNT	169	73	346	7	256	1	27	0	6	6	892
	ROW PCT	19.0	8.2	38.8	0.8	28.8	0.1	3.1	0.0	0.7	0.6	7.2
	COL PCT	4.4	6.2	13.2	0.9	10.1	0.2	5.7	0.5	12.3	3.1	
	TOT PCT	1.4	0.6	2.8	0.1	2.1	0.0	0.2	0.0	0.0	0.0	
4. SANDUSKY @ MEX	COUNT	110	46	177	0	150	0	20	0	5	5	514
	ROW PCT	21.4	8.9	34.4	0.1	29.2	0.0	3.9	0.0	1.1	1.0	4.2
	COL PCT	2.9	3.9	6.7	0.0	5.9	0.0	4.1	0.5	11.7	2.7	
	TOT PCT	0.9	0.4	1.4	0.0	1.2	0.0	0.2	0.0	0.0	0.0	
5. SANDUSKY @ UP SA	COUNT	43	22	74	0	82	0	11	0	2	2	235
	ROW PCT	18.4	9.3	31.3	0.0	34.7	0.0	4.6	0.0	0.8	0.9	1.9
	COL PCT	1.1	1.9	2.8	0.0	3.2	0.0	2.2	0.0	4.0	1.2	
	TOT PCT	0.4	0.2	0.6	0.0	0.7	0.0	0.1	0.0	0.0	0.0	
6. SANDUSKY @ HUC	COUNT	13	7	28	0	27	0	4	0	0	1	80
	ROW PCT	15.9	8.6	35.2	0.0	33.7	0.0	4.8	0.0	0.6	1.1	0.6
	COL PCT	0.3	0.6	1.1	0.0	1.1	0.0	0.8	0.0	1.1	0.5	
	TOT PCT	0.1	0.1	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	
7. TYMOCHTEE @ CRAW	COUNT	41	10	43	0	22	0	3	0	1	1	121
	ROW PCT	34.0	8.4	35.7	0.1	17.9	0.0	2.4	0.0	1.0	0.6	1.0
	COL PCT	1.1	0.9	1.7	0.0	0.9	0.0	0.6	0.0	2.5	0.4	
	TOT PCT	0.3	0.1	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	
COLUMN TOTAL		3811	1175	2625	790	2544	626	485	20	47	185	12308
		31.0	9.5	21.3	6.4	20.7	5.1	3.9	0.2	0.4	1.5	100.0

NOTE: Count is in square miles (top no. in each block)
All other figures are percentages.

Table 6. Three-way Co-occurrence

COOCCURRENCE TABLES 11/07/78

FILE NFL (CREATION DATE = 11/07/78) BUFFALO DIST.,COE LAKE ERIE LRIS

* C R O S S T A B U L A T I O N O F * * * * * * * * * * * *

TEXT TEXTURE OF SURFACE HORIZON BY LU MAJOR LAND USE CATAGORIES

CONTROLLING FOR..

BASIN SAMPLING STATION BASIN VALUE = 34. CATTARAUGUS @ GO

* *

TEXT		COUNT / ROW PCT / COL PCT / TOT PCT (LU)	CROPLAND 1.	VINEYARD 2.	PASTURE 3.	FOREST 4.	WATER 5.	OTHER 6.	ROW TOTAL
SILTCLAYLOAM	2.1	COUNT	0	0	0	0	0	0	0
		ROW PCT	0.0	0.0	50.0	50.0	0.0	0.0	0.0
		COL PCT	0.0	0.0	0.3	0.1	0.0	0.0	
		TOT PCT	0.0	0.0	0.0	0.0	0.0	0.0	
LOAM	3.1	COUNT	22	0	2	8	1	6	39
		ROW PCT	55.7	0.0	5.3	21.4	2.3	15.3	9.7
		COL PCT	12.7	0.0	7.1	5.4	12.3	16.6	
		TOT PCT	5.4	0.0	0.5	2.1	0.2	1.5	
SILTY LOAM	3.2	COUNT	147	1	27	142	6	28	352
		ROW PCT	41.8	0.3	7.7	40.5	1.8	7.9	87.3
		COL PCT	85.3	100.0	92.2	90.9	84.9	77.3	
		TOT PCT	36.5	0.3	6.7	35.3	1.5	6.9	
VFSANDY LOAM	3.3	COUNT	0	0	0	1	0	0	2
		ROW PCT	21.1	0.0	0.0	68.4	0.0	10.5	0.5
		COL PCT	0.2	0.0	0.0	0.8	0.0	0.6	
		TOT PCT	0.1	0.0	0.0	0.3	0.0	0.0	
SANDY LOAM	4.1	COUNT	2	0	0	3	0	1	5
		ROW PCT	32.7	0.0	0.0	49.1	3.6	14.5	1.4
		COL PCT	1.0	0.0	0.0	1.7	2.7	2.2	
		TOT PCT	0.4	0.0	0.0	0.7	0.0	0.2	
FN SANDYLOAM	4.2	COUNT	1	0	0	1	0	0	2
		ROW PCT	57.1	0.0	0.0	33.3	0.0	9.5	0.5
		COL PCT	0.7	0.0	0.0	0.4	0.0	0.6	
		TOT PCT	0.3	0.0	0.0	0.2	0.0	0.0	
MUCK	6.1	COUNT	0	0	0	1	0	1	2
		ROW PCT	4.5	0.0	4.5	45.5	0.0	45.5	0.5
		COL PCT	0.1	0.0	0.3	0.6	0.0	2.8	
		TOT PCT	0.0	0.0	0.0	0.2	0.0	0.2	
COLUMN TOTAL			173	1	29	157	7	36	403
			42.8	0.3	7.3	38.8	1.8	9.0	100.0

CHI SQUARE = 14.39355 WITH 30 DEGREES OF FREEDOM SIGNIFICANCE = 0.9927

CRAMER'S V = 0.08448

NOTE: Count is in square miles (top no. in each block)
All other figures are percentages.

Initial tables prepared include the following variables, (Tables 7 & 8) for each of the 71 chemical sampling stations in the basin, as well as the direct drainage area and un-gaged portions of basins. The grouping of variables are shown on Table 9, but different groupings can be formed by a slight program change, if desired. The Users Manual summarizes the program steps, program names, and data sets developed to produce these tables.

Table 7. Two-way Co-occurrence Tables

Variable		Variable
Basin	by	Permeability
Basin	by	Land Use
Basin	by	Slope
Basin	by	Texture
Basin	by	Drainage Code
Basin	by	Intrinsic Erodibility

Table 8. Three-way Co-occurrence Tables
Variables Summarized by Basin

Variable		Variable
Slope	by	Land Use
Soil Texture	by	Land Use
Soil Texture	by	Slope
Soil Texture	by	Intrinsic Erodibility
Land Use	by	Intrinsic Erodibility
Slope	by	Intrinsic Erodibility
Permeability	by	Slope
Land Use	by	Drainage Class
Land Use	by	Land Capability Class
Permeability	by	Land Use

Table 9. Variable Categories

```
LU      MAJOR LAND USE CATAGORIES
           1. CROPLAND
           2. VINEYARD
           3. PASTURE
           4. FOREST
           5. WATER
           6. OTHER
MISS       9. MISSING

AREA

TEXT    TEXTURE OF SURFACE HORIZON
           1.1 CLAY
           1.2 SILTY    CLAY
           1.3 SANDY    CLAY
           2.1 SILTCLAYLOAM
           2.2 CLAY     LOAM
           2.3 SANDCLAYLOAM
           3.1 LOAM
           3.2 SILTY    LOAM
           3.3 VFSANDY LOAM
           3.4 SILT
           4.1 SANDY    LOAM
           4.2 FN SANDYLOAM
           5.1 SAND
           5.2 FINE     SAND
           5.3 VFINE    SAND
           5.4 LOAMY    SAND
           5.5 LOAMFINESAND
           5.6 LOAMY VFSAND
           6.1 MUCK
           7.1 NONSOIL
           7.2 URBAN LOCOMP

DUN URBAN SLOPE VALUE (%)
           0.2 LESSTHAN 0.2
           0.5 0.5
           1.0 1.0
           2.0 2.0
           4.0 3-5
           7.0 6-8
          10.0 9-11
          13.0 12-14
          16.0 15-17
          18.0 18 OR   GREATER

PERM    PERMEABILITY,LOW VALUE IN HORIZ.,IN P HR
           1. SURF .01 TO 0.09
           2. BELO .01 TO 0.09
           3. all  .10 TO 0.19
           4. all  .20 TO 0.59
           5. all  .60 TO 1.9
           6. all  2.0 TO 5.9
           7. all  6.0 OR GTR

KFAC    INTRINSIC ERODABILITY (K)
           0.10 0.10
           0.15 0.15
           0.17 0.17
           0.20 0.20
           0.24 0.24
           0.28 0.28
           0.32 0.32
           0.37 0.37
           0.43 0.43
           0.49 0.49

CAP     LAND CAPABILITY CLASS,WITH LIMITS
           1. 1
           2. 2S
           3. 2E
           4. 2W
           5. 3S
           6. 3E
           7. 3W
           8. 4S
           9. 4E
          10. 4W
          11. 5S
          12. 5E
          13. 5W
          14. 6S
          15. 6E
          16. 6W
          17. 7S
          18. 7E
          19. 7W
MISS      20. OTHER

DRCO    DRAINAGE CHARACTERISTICS CODE
           1. VERYPOORDRAINED
           2. POORLY   DRAINED
           3. SOMEPOORDRAINED
           4. MOD.WELLDRAINED
           5. WELL     DRAINED
           6. SOMEEXCEDRAINED
           7. EXCESVLYDRAINED
```

LRIS Variables

The information as encoded in the LRIS can describe a selected basin or land area in two different ways. First, the composition of a basin in terms of a selected variable, such as land use, can be summarized by the percentage of different types of land use (i.e., 72% agricultural land) as a function of the basin as a whole. For a variable such as slope, the different catagories (ranging from 0.2% to 35%) can be stated, or an <u>average</u> slope value calculated based on the basin composition. For soil derived characteristics, such as permeability, texture, erodability or drainage class, the ranges of values are grouped and ranked according to some scheme. These are discussed briefly in the following section as listed in Table 9.

Permeability

The SCS-5 records used to describe the various unique soil phases included in the LRIS (some 3,131 in all) list permeability as a <u>range</u> of values by horizon, such as 0.2 to 0.6 inches per hour, "A" horizon, 0.6 to 2.0 inches per hour, "B" horizon, etc. For this analysis, the lowest value (least permeable) in a range was selected as descriptive of the soil, and classified as follows: class (1), "A" horizon with perm $\angle$ 0.09 in/hr; class (2) lower horizons with perm $\angle$ 0.09 in/hr; (3) <u>any</u> horizon $\angle$ 0.09 in/hr, etc. This classification attempted to rank the soil types by their tendency to produce overland runoff, with special emphasis on

the surface ("A") horizon. No attempt was made to weigh the thickness of the various horizons, although such a scheme could be developed. There are seven perm classes, with the highest being all horizons with a perm greater than or equal to 6.0 inches/hr.

Texture

Initially, almost 150 textures were described in the raw LRIS files, but as complexes and variants were assigned to specific major texture groups, the number of unique soil textures was reduced to several dozen. These in turn were grouped into five major categories recommended by the SCS, ranging from heavy clays to sands. The muck and highly organic soils were distinguished separately as category 6. This final texture classification is shown in Table 10.

Drainage Class

Each major soil series in the SCS-5 record is described literally as to general drainage characteristics (i.e., "moderately to well drained silt loam...""). These various descriptive terms were screened and seven drainage classes created, from very poorly drained (DRCO =1) to excessively well drained (DRCO =7). This is also shown in Table 9.

Intrinsic Erodibility

This variable, the "K" factor, is also described by % of different values, from 0.10 to 0.49, for each basin. An average value could also be calculated easily, but again it is felt that such averages are poor basin descriptors for the purposes of this analysis.

Table 10. Soil Texture Codes

SOIL TEXTURE	CODE NO.	SYMBOL	LRIS TEXTURE CODES INCLUDED (last 4 fields of SHORTPROP TEXTURE)
Clay	1.1	C	
Silty clay	1.2	SIC	SIC, KSIC,-SIC,USIC
Sandy Clay	1.3	SC	SC
Silty Clay loam	2.1	SICL	SICL
Clay Loam	2.2	CL	CL,K-CL,MUCL,R-CL
Sandy Clay loam	2.3	SCL	SCL
Loam	3.1	L	L,BGRL,CBL,CNL,FGRL, GR-L,RF-L,GRL,GRVL, SHL,SLL,ST-L,STL,VCNL, SHL,SLL,ST-L,STL,VCNL, VSTL,MUL,TV-L,MK-L,CN-L, RV-L,SH-L,NV-L,CB-L,IL-L,IL&L
Silty Loam	3.2	SIL	KSIL,-SIL,SIL,USIL,&SIC
VF Sandy Loam	3.3	VFSL	VFSL
Silt	3.4	SI	none in file
Sandy Loam	4.1	SL	SL,B-SL,CNSL,COSL,R-SL, N-SL,GRSL
FN Sandy Loam	4.2	FSL	FSL,UFSL,NFSL
Sand	5.1	S	S
Fine Sand	5.2	FS	FS,K-FS,MUFS
Very Fine Sand	5.3	VFS	VFS
Loamy Sand	5.4	LS	LS,MULS,R-LS,GRLS,RVLS, V-LS,K-LS
Loamy Fine Sand	5.5	LFS	LFS,KLFS,-LFS
Loamy VF Sand	5.6	LVFS	LVFS
Muck	6.1	MU	MU,MARL,MUCK,MUMR,SIMU, PT,PEAT
Non-Soil	7.1	N	N,NL,NSL
Urban	7.2	U	U,UVT

Potential Soil Erosion Analysis by the USLE

One of the more interesting analyses derived from the LRIS has been the calculation of potential gross soil erosion, using the Universal Soil Loss Equation or USLE (SCS, 1971). The equation has become the cornerstone of erosion analysis by SCS soil scientists over the past fifteen years and serves as an excellent method of evaluating soil and terrain conditions for recommendation of agricultural land management practices. The form of the equation is such that it uses parameters derived from soil texture, long term precipitation, land cover and land slope to estimate a potential erosion of soil in terms of mass (tons) per unit area (acre) per unit time (year). The terms of the equation are as follows:

A (soil erosion in T/ac/yr) = K (LS) RC

where

K = intrinsic erodability of soil (dimensionless)

LS = function of slope and slope length

R = Rainfall factor

C = Cover factor

Various references (USDA, 1976) document the development and derivation of these parameters in detail and so a full explaination is not presented here.

Slope, slope length, and intrinsic erodability are some of the soil properties listed in the Short Property File for each unique soil phase in the Lake Erie Basin. Slope and slope length estimates were made by SCS scientists based on series name and slope range from county surveys. Intrinsic erodability was obtained from national SCS-5 files by series name and from project

SCS scientists where this data was not in the SCS-5 files. The "LS" factor used in USLE is calculated from the slope and slope length of each unique soil phase, according to the following equation:

$$LS=(SL/72.6)^{m}(430(S/100)^{2}/(1+(S/100)^{2})+30\frac{\sqrt{(S/100)^{2}}}{1+(S/100)^{2}}+.43$$

divided by 6.574

where

SL = slope length

S = Slope

M = 0.5 for slopes over 4.1%

0.4 " " 3.1 - 4.1

0.3 " " 2.1 - 3.0

0.2 " " less than 2.1%

Also estimated independent of the LRIS were "C" factors for various existing crop management conditions and "R" factors by County (Tables 11 and 12). With this information, it was possible to calculate the potential gross erosion within defined areas of the data base; for initial runs the 71 major chemical sampling stations were chosen.

The analysis began with the assignment of length values (Urban, 1978) to soil phases based on the soil scientist's experiences with many of the soils in the file and a review of local practices and surface drainage conditions. Also, for incomplete soil records, values of slope and a confidence code were assigned. Values of "K" wore also chosen if missing from the SCS-5 record. Finally, a grouping of soils into "Soil Management Group" (SMG) categories was carried out (Table 13) to allow the development of various scenarios for reduction of gross erosion. The rational behind this grouping is discussed

Table 11. Average Cover Factors (C) for Cropland and Rainfall Values (R) by County

COUNTY NO.	NAME	R	C_1	C_2	C_3	C_4	C_5	C_6
1	MUNRUE, MICH	113	.236	.224	.238	.236	.103	.034
2	CRAWFORD, O	125	.240	.229	.255	.233	.104	.034
3	SENECA, O	125	.237	.225	.255	.237	.105	.035
4	HURON, O	125	.253	.241	.265	.242	.106	.035
5	OTTAWA, O	125	.237	.223	.250	.223	.103	.032
6	SANDUSKY, O	125	.268	.257	.285	.255	.108	.032
7	ERIE, O	125	.257	.243	.271	.246	.106	.033
8	WOOD, O	125	.273	.256	.284	.256	.109	.034
9	LUCAS, O	125	.261	.249	.273	.254	.108	.036
10	HANCOCK, C	138	.265	.250	.275	.252	.107	.034
11	WYANDOT, C	138	.260	.252	.278	.254	.108	.035
12	HARDIN, O	138	.253	.243	.268	.244	.107	.033
13	MARION, C	138	.269	.258	.286	.256	.108	.033
14	RICHLAND, O	138	.164	.162	.182	.164	.090	.032
15	HENRY, O	138	.281	.262	.289	.260	.109	.034
16	ASHLAND, C	138	.109	.107	.126	.109	.075	.030
17	MEDINA,O	138	.148	.140	.160	.144	.075	.028
18	CUYAHOGA, O	125	.138	.136	.157	.135	.068	.021
19	SUMMIT, O	138	.064	.062	.078	.064	.065	.030
20	LAKE, O	125	.171	.169	.193	.164	.074	.021
21	GEAUGA, O	125	.046	.045	.054	.046	.044	.021
22	PORTAGE, C	138	.144	.142	.159	.144	.076	.029
23	STARK, O	138	.144	.142	.159	.144	.076	.029
24	ASHTABULA, O	125	.060	.059	.072	.060	.053	.024
25	TRUMBULL, O	138	.127	.125	.142	.127	.068	.025
26	ERIE, P	125	.093	.091	.106	.092	.054	.020
27	CRAWFORD, P	138	.080	.078	.093	.080	.053	.022
28	CHAUTAUQUA, NY	113	.152	.150	.172	.152	.059	.021
29	ERIE, NY	100	.085	.083	.097	.085	.064	.020
30	CATTARAUGLS, NY	113	.152	.150	.172	.152	.059	.021
31	WYOMING, NY	100	.107	.105	.121	.107	.068	.026
32	SANILAC, M	75	.067	.066	.075	.067	.060	.028
33	LAPEER, M	88	.072	.071	.082	.072	.058	.022
34	ST. CLAIR, M.	88	.069	.068	.080	.069	.054	.023
35	INGHAM, M	100	.090	.089	.102	.090	.074	.026
36	LIVINGSTCN, M	100	.090	.089	.102	.090	.074	.026
37	OAKLAND, M	100	.055	.054	.066	.055	.041	.018
38	MACOMB, M	100	.150	.148	.171	.148	.083	.030
39	JACKSON, M	113	.151	.149	.168	.151	.075	.027
40	WASHTENAW, M	100	.117	.115	.133	.114	.062	.023
41	WAYNE, M	113	.181	.179	.199	.181	.095	.034
42	BRANCH, M	125	.162	.156	.176	.162	.090	.031
43	HILLSDALE, M	125	.162	.156	.176	.162	.090	.031
44	LENAWEE, M	113	.247	.235	.259	.238	.105	.034
45	STEUBEN, I	138	.199	.189	.215	.189	.095	.029
46	WILLIAMS, O	138	.242	.230	.254	.235	.104	.035
47	FULTON, O	125	.290	.275	.304	.269	.111	.033
48	NOBLE, I	150	.232	.221	.249	.220	.102	.031
49	DEKALB, I	150	.254	.239	.268	.237	.106	.032
50	DEFIANCE, O	138	.263	.247	.270	.249	.107	.036
51	LORAIN, O	125	.184	.175	.198	.181	.094	.031
52	ALLEN, I	150	.266	.250	.277	.250	.108	.034
53	PAULDING, O	150	.251	.235	.255	.243	.106	.038
54	PUTNAM, O	138	.264	.250	.278	.248	.107	.033
55	WELLS, I	160	.293	.281	.312	.274	.112	.033
56	ADAMS, I	160	.271	.257	.286	.254	.108	.033
57	VANWERT,O	150	.292	.277	.306	.273	.112	.034
58	ALLEN, O	150	.268	.254	.282	.256	.108	.034
59	MERCER, C	160	.233	.223	.249	.225	.103	.033
60	AUGLAIZE, O	150	.226	.216	.241	.220	.101	.032
61	SHELBY, C	150	.226	.216	.241	.220	.101	.032
63	ALLEGANY, NY	100	.152	.150	.172	.152	.059	.021

Table 12. Cropland Cover Factors

C_1	Present Condition
C_2	Spring Plow, Residue Left
C_3	Fall Plow, Residue Left
C_4	Winter Cover
C_5	Conservation Tillage, Mulch
C_6	Conservation Tillage, No-Till

Table 13. Soil Management Groups (SMG)

Group No.	Description
1.	Excessive, well and moderately well drained soils.
2.	Somewhat poorly and very poorly drained soils which have good response to surface or subsurface drainage.
3.	Somewhat poorly and poorly drained soils with slow permeability that show little or no response to reduced tillage even with subsurface drainage.
4.	Very poorly drained soils with fine textured surfaces and relatively high amounts of organic matter, response to subsurface drainage is good but mulch cover retards warming of the soil in the spring.
5.	Organic soils, alluvial soils and other soils with slow permeability and relatively high clay contents.
6.	Group 2 soils with clay or silty clay surface textures.
7.	Group 3 soils with clay or silty clay surface testures.
8.	Group 4 soils with clay or silty clay surface textures.
9.	Group 5 soils with clay or silty clay surface textures.
10.	All soil types with slopes in excess of 18%.

in the following paragraph.

The scenarios proposed (Table 14) are designed to evaluate the impact of various management options against the present condition. The present condition is based on the combination of row crop, small grain and hayland in a county, as reported by the Crop Reporting Service for 1976 and modified to reflect prevalence of fall and spring plowing.

Each soil type and soil phase has been assigned a Tillage Group or Soil Management Group (SMG). These groups will permit the comparison of various options and reduce the data processing time required for analysis. It should also be kept in mind that these comparisons are designed to be done on a drainage basin basis. It is done on this basis in order to reflect the impact of the options on the unique combination of soils, slope, slope length, surface texture and land use within a given basin.

These Soil Management Groups also become a method of evaluating the economic impact, as described elsewhere, (Forster, 1978).

Table 15 is a description of the various "C" factors which were assigned by scenario to each SMG; for example, in scenario 8, the impact of applying conservation tillage to SMG 2 and SMG 6, while not altering existing practices on other SMG's, results in the use of a "C" factor of 5 on SMG 2 and 6, with "C" factor 1 on all others.

The resulting computer summary of this analysis is shown in Table 16, by summing the figures encircled. That is, the gross tonnage resulting from the 339,353 acres of SMG 1, total-

Table 14. Cropland Management Scenario Description

Scenario No.	Description
1	Present Conditions
2	Present Conditions with potential soil loss (A) limited to tolerance factor (T)
3	Spring Plowing, all SMG's
4	Spring Plowing, SMG 1,2,3,4,5,10
5	Fall plowing, SMG 6,7,8,9
6	Winter Cover, all SMG's
7	Conservation Tillage, mulch, SMG 1
8	Conservation Tillage, SMG 2,6
9	Conservation Tillage, SMG 3,7
10	Conservation Tillage, SMG 4,8
11	Conservation Tillage, No-Till, SMG 1
12	Conservation Tillage, No-Till, SMG 2,6

NOTE: Other selective combinations can be made from computer-generated output such as Table 16 to create any desired scenario. Example shown as circled values is scenario 8, above. PGE for non-cropland must be added, as shown.

Table 15. C Factors Applied by Scenario and Soil Management Group

SMG	Scenario 1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	2	2	1	4	5	1	1	1	6	1
2	1	1	2	2	1	4	1	5	1	1	1	6
3	1	1	2	2	1	4	1	1	5	1	1	1
4	1	1	2	2	1	4	1	1	1	5	1	1
5	1	1	2	2	1	4	1	1	1	1	1	1
6	1	1	2	1	3	4	1	5	1	1	1	6
7	1	1	2	1	3	4	1	1	5	1	1	1
8	1	1	2	1	3	4	1	1	1	5	1	1
9	1	1	2	1	3	4	1	1	1	1	1	1
10	1	1	2	2	1	4	1	1	1	1	1	1

A See Table 14 for Scenario Description.

Table 16. USLE Analysis Output

ARMY CORPS OF ENGINEERS
BUFFALO DISTRICT: LEWMS
ESTIMATION OF POTENTIAL
GROSS EROSION BY USLE
AND LRIS(MAIN FILE)

MAUMEE @ WATERVILLE
SAMPLING STATION NO. 1
STA. TYPE:LOWST IN BSN
CO: ALL IN BASIN
COUNTY NUMBER: 62

	1 PRESENT CONDITION	2 CONFORM TO TFAC IF PGE GT TFAC	3 PRESENT CONDITION IF PGE LE TFAC	4 SOIL SAVED IF TFAC MET 4=1-(2+3)	5 SPRING PLOWED RESIDUE LEFT	6 FALL PLOW RESIDUE LEFT	7 WINTER COVER	8 CONSERV. TILL: MULCH	9 CONSERV. TILL: NO TILL
	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR. ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR
	C1				C2	C3	C4	C5	C6
	SCENAR 1	(SCENARIO 2=2+3)			SCENAR 3		SCENAR 6		
CROPLAND	3183817.0	852897.3	248090.9	2082828.0	3019980.0	3355143.0	3036748.0	1353821.0	430423.8
SMG	339358.7	245320.3	92614.7	245320.3	339358.7	339358.7	339358.7	339358.7	339358.7
1	9.4	3.5	2.7	8.5	8.9	9.9	8.9	4.0	1.3
CROPLAND	3554123.0	1579580.0	584685.8	1389857.0	3369771.0	3736743.0	3387551.0	1477111.0	468767.6
SMG	850935.0	522574.8	328271.1	522574.8	850935.0	850935.0	850935.0	850935.0	850935.0
2	4.2	3.0	1.8	2.7	4.0	4.4	4.0	1.7	0.6
CROPLAND	431320.8	219873.6	115152.0	96365.2	407941.2	450794.0	411219.1	182649.1	59685.4
SMG	114110.3	73923.8	40186.7	73923.8	114110.3	114110.3	114110.3	114110.3	114110.3
3	3.8	3.0	2.9	1.3	3.6	4.0	3.6	1.6	0.5
CROPLAND	934835.1	0.0	934835.1	0.0	881948.8	974859.6	881467.0	376524.9	118857.9
SMG	865494.7	0.0	864872.0	0.0	865494.7	865494.7	865494.7	865494.7	865494.7
4	1.1	0.0	1.1	0.0	1.0	1.1	1.0	0.4	0.1
CROPLAND	347290.9	5982.4	277113.7	64194.8	328033.7	361787.1	330703.0	144646.7	47294.4
SMG	243383.3	2513.1	240870.3	2513.1	243383.3	243383.3	243383.3	243383.3	243383.3
5	1.4	2.4	1.2	25.5	1.3	1.5	1.4	0.6	0.2
CROPLAND	249.7	0.0	249.7	0.0	239.8	264.5	240.8	105.6	32.6
SMG	266.9	0.0	266.9	0.0	266.9	266.9	266.9	266.9	266.9
6	0.9	0.0	0.9	0.0	0.9	1.0	0.9	0.4	0.1
CROPLAND	10561.8	0.0	10561.8	0.0	9909.5	10796.6	10139.9	4402.3	1534.9
SMG	4625.8	0.0	4625.8	0.0	4625.8	4625.8	4625.8	4625.8	4625.8
7	2.3	0.0	2.3	0.0	2.1	2.3	2.2	1.0	0.3
CROPLAND	44813.3	0.0	44813.3	0.0	42383.2	46751.0	42433.5	18141.8	5786.7
SMG	38629.9	0.0	38629.9	0.0	38629.9	38629.9	38629.9	38629.9	38629.9
8	1.2	0.0	1.2	0.0	1.1	1.2	1.1	0.5	0.1
CROPLAND	203528.4	8480.6	154772.5	40275.3	191588.6	210415.3	193871.7	83998.3	28029.9
SMG	131934.3	3034.5	128899.9	3034.5	131934.3	131934.3	131934.3	131934.3	131934.3
9	1.5	2.8	1.2	13.3	1.5	1.6	1.5	0.6	0.2
CROPLAND	375451.5	12298.3	0.0	363353.3	354302.3	390692.8	357822.7	155388.7	50740.1
SMG	4447.9	4447.9	0.0	4447.9	4447.9	4447.9	4447.9	4447.9	4447.9
10	84.4	2.7	0.0	81.7	79.7	87.8	80.4	34.9	11.4
SUMMARY	9086061.0	2678906.0	2370267.0	4036388.0	8606101.0	9538250.0	8652196.0	3796787.0	1211150.0
CROPLAND	2593176.0	851814.3	1739233.0	651814.3	2593176.0	2593176.0	2593176.0	2593176.0	2593176.0
SMG 1-10	3.5	3.1	1.4	4.7	3.3	3.7	3.3	1.5	0.5

Table 16. Continued

VINEYD &	669.4	266.9	253.9	148.7					
ORCH, SMG	296.5	89.0	207.6	89.0					
1	2.3	3.0	1.2	1.7					
VINEYD &	156.7	0.0	156.7	0.0					
ORCH, SMG	160.6	0.0	160.6	0.0					
2	1.0	0.0	1.0	0.0					
VINEYD &	26.9	0.0	26.9	0.0					
ORCH, SMG	89.0	0.0	89.0	0.0					
4	0.3	0.0	0.3	0.0					
VINEYD &	29.1	0.0	29.1	0.0					
ORCH, SMG	89.0	0.0	89.0	0.0					
5	0.3	0.0	0.3	0.0					
* SUMMARY *	882.1	266.9	466.6	148.7					
* VINEORCH *	635.1	89.0	546.1	89.0					
* SMG 1-10 *	1.4	3.0	0.9	1.7					
GRASSLAND	7882.9	0.0	7882.9	0.0					
	112168.1	0.0	112079.1	0.0					
	0.1	0.0	0.1	0.0					
WOODLAND	27341.6	711.7	26523.9	106.1					
	280947.9	355.8	280414.1	355.8					
	0.1	2.0	0.1	0.3					
* SUBTOTAL *	9122150.0	2679885.0	2405132.0	4037133.0	8642191.0	9574344.0	8688292.0	3832884.C	1247252.0
* *	2986919.0	852259.0	2132263.0	852259.0	2986919.0	2986919.0	2986919.0	2986919.C	2986919.0
* *	3.1	3.1	1.1	4.7	2.9	3.2	2.9	1.3	0.4
WATER AREA ONLY	105207.1								
OTHER LAND USE AREA ONLY	320487.1								
MISSING LAND USE AREA ONLY	207.6								
MISSING SOILDATA AREA ONLY	629024.9								
TOTALS FOR	9122150.0	2679885.0	2405132.0	4037133.0	8642191.0	9574344.0	8688292.0	3832884.C	1247252.0
THIS TABLE	4041830.0	852259.0	2132263.0	852259.0	4041830.0	4041830.0	4041830.0	4041830.C	4041830.0
* *	2.3	3.1	1.1	4.7	2.1	2.4	2.1	0.5	0.3

ling 3.18 million tons/year, is added to the present condition totals for all SMG's except 2 and 6. For SMG 2, column 8, conservation tillage applied to 850,935 acres of SMG 2 results in a gross erosion potential of 1.47 million tons, instead of 3.55 million tons. The output tables are structured to include the results of <u>all</u> scenarios for <u>all</u> SMG's, so that one need only sum the appropriate column entry by SMG, as shown, for a desired result. The inclusion of non-cropland erosion, shown in rectangle, must not be forgotten for the basin total.

The USLE Analysis Output shown in Table 16 reflects a series of steps that took the LRIS counted data and created a set of intermediate data which led to the results shown. While the complete set of intermediate and final programs are described fully in the Users Manual, it is informative to list the general procedure used to produce this USLE analysis;

1. The unaggregated LRIS data was sorted by basin municipality soil phase, and land use.
2. The sorted unaggregated LRIS data was counted on area.
3. The sorted counted unaggregated LRIS data was aggregated on all four factors: subbasin to sampling station, municipality to county, soil phase number to a pointer to the property file, and land use to USLE land cover categories.
4. The aggregated LRIS data from step 3 was then sorted on each factor in the order given above.
5. The sorted,aggregated LRIS data was counted on area for each unique sampling station, county, pointer and

land cover combination.

6. The sorted, counted, aggregated LRIS data was then read in for processing one record at a time. The pointer was used to pull in K, slope, slope length, tolerance factor(T) and SMG. The value for county was used to obtain the R factor. After calculating the LS factor, area*R*K * LS was determined and stored with the associated values for sampling station, county, land use, SMG, T and area.

7. The area RKLS file from step 6 was sorted on sampling station, land use, SMG and T and then counted for area for all unique combinations of the forementioned.

8. The sorted counted area RKLS file was then read in to the final USLE program for processing for cropland and calculated. The potential gross erosion (PGE in tons/acre/year) rate for each cropland record was calculated by SMG for each of six county-dependent cover values. The first C value represents present conditions, and the other C values represent five alternative management possibilities. The PGE for vineyards, grassland and forest were calculated for present conditions only. The land use codes used in the USLE analysis were collapsed as shown in Table 17 for this set of programs only.

Table 17. Land Use Codes for USLE Analysis

USLE Code	General Land Use	LRIS Land Use Codes Included
1	Cropland	20,21,22,24,26,29,30
2	Vineyard/orchard	23
3	Grassland	16,18,25,27,28,31,84,87
4	Woodland	41-45
5	Water	51-55
6	Other land uses	8-15,17,19,61,62,71-76,81-83, 85,86,88

Map Products

One of the most powerful capabilities of a computerized resource data system, such as the LRIS, is the ability to display or generate the data in graphic form. This means not only the raw encoded data, such as land use and soils, but also selected results of analysis on that data, such as the gross soil erosion or land management suitability. Since the initial data is encoded in a fixed data structure and collapsed for subsequent analysis, the task of displaying the results is not a simple matter, but requires special programs to create map files in a manner and form dependent on the output mode. That is, to produce a map of soil management groups at a precise scale (say 1:50,000) by a CALCOMP Plotter Devise is a different task than displaying the same data on a color CRT. Since the initial requirements of this study include the production of color maps at 1:1,000,000 for selected factors, a set of programs were developed to accomplish this from the LRIS files, using a DICOMED process at the University of Minnesota, Special Interactive Computation Laboratory. The preparitory programs and the color coding scheme are described in the Users Manual. The final maps are on 16" x 25" paper and are shown separately. Other map products will be developed during 1979 both in color and ink on mylar.

In order to produce maps of all or large portions of LRIS, the region section format must be restructured. All LRIS information in a west to east row across the mapping area is brought together into one computer record from the various LRIS Section-regions in which it is found. As this is done, the raw LRIS

codes are aggregated or used to call ancillary data or used in calculations to produce final mapping codes.

LRIS was used to produce six color maps of the whole U.S. side of the Lake Erie Basin (See Table 18).

Table 18. Initial Map Products

Color Map	Data Files Used			
	BASIN	POLITICAL	LAND USE	SOIL
1. Land Use			+	
2. Soil Texture				+
3. Slope				+
4. KLS (component of USLE)				+
5. Soil Management Group				+
6. Potential Gross Erosion		+	+	+

It is possible to produce maps of any single factor or combination of factors or their supporting data files. One is referred to the listings of unaggregated (raw) codes in LRIS to appreciate the potential of LRIS for many different kinds of maps.

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